Biotechnology business in Norway: Peripheral advantage, or just periphery?

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Abstract

Research on biotechnology related firms has long been associated with the agglomeration of "dedicated biotechnology firms" and partners such as large corporations, research institutes and venture capital firms. At the same time it is acknowledged that such agglomeration trends may be most closely associated with medical biotechnology. This paper shows that there are more than 130 firms which may be classified as biotechnology related firms in Norway. Furthermore they are spread out throughout the country, albeit with more than half being located in the Eastern part. While there is indeed a great preoccupation with medical biotechnology also in Norway, the survey shows that two other distinct traits are present: a concentration of firms being focused on diagnostics and drug delivery rather than on therapeutics, and a focus on marine biotechnology (more than one third of the firms) within nutrition related products rather than or in addition to medical products. In addition to contributing these descriptive findings the paper thus opens up the agglomeration discussion, and suggests that foci on such niches as those which are prevalent in Norway may function with geographical distribution patterns different from those prevalent within the current medical biotechnology focused literature.

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Introduction

Research on the successful establishment and growth of firms has increasingly been focused on the relationship between internal competencies and the external environment (Powell et al. 1996; Owen-Smith et al. 1996; Mitra 2000; Pisano 2000). Appropriate organizational capabilities may be interpreted as a main factor behind a firm's success in a particular marketplace. However, environmental factors have also have been highlighted as essential for certain industries, such as biotechnology (Bartholomew 1997; Senker 1996). For "dedicated biotechnology firms" (DBFs),[1] proximity to partners such as large corporations or venture capital firms can bring external resources and competencies to the biotechnology firms (Bagchi-Sen 2007). In addition, due to the science-based nature of many biotechnology firms, the role of policy comes into the forefront in the sense of supporting the growth of an R&D infrastructure, securing an adequate supply of science and technology graduates, and smoothing the relationships with universities and public research institutes. In sum it has been proposed that "networks of DBFs, venture capital firms, large corporations and research institutions are key in the dynamics of biotechnology" (Niosi 2003: 738). Eliasson (2000) has presented a similar view consisting in emphasizing the symbiotic relationships between actors, whereas others more recently have questioned whether this kind of agglomeration based development is and should be the only one for biotechnology based activities (Nightingale and Martin 2004). A large proportion of the literature is focused on biopharmaceuticals (McKelvey and Orsenigo 2006, as cited in Brink et al. 2007: 733), and although agglomeration may very well be beneficial for actors within biopharmaceuticals, the benefits may not be as evident for other biotechnology related activities such as agricultural or industrial biotechnology (Brink et al. 2007).

Norway is a small country in economic and population terms, and is in addition geographically distant from science-based centers such as e.g. the United Kingdom. This paper starts with the observation that there exist nevertheless biotechnology related firms in Norway, and subsequently describes the current activities of the Norwegian DBFs and other firms involved in biotechnology in terms of their product specialization areas, numbers, and geographical distribution. The overview also considers the relationship, if any, between biotechnology firms and universities and public research institutes, large corporations and venture capital firms. According to the first of the views cited above one could assume that the likelihood for the emergence of a viable network of biotechnology firms, venture capital firms, large corporations and research institutions is limited due to Norway's distant location from science based centers and its small indigenous human and organizational population base. Are there nevertheless networks in this Niosi (2003) sense even in Norway, or are there just pockets of random activities**?** Does Norway's location on the "periphery" mean that the existing biotechnology business in Norway is doomed to failure? Alternatively, is it actually the case as portrayed within public policy and parts of the industry press (NHD 1998; Aldridge 2005; RMV 2003: 14), that Norway displays strengths within other kinds of biotechnology activities such as within marine biotechnology in the sense of biotechnology activities being focused on organisms from the oceans,[2] and that the Norwegian case subsequently displays fundamentally different dynamics than the network-based dynamics emphasized in the literature?

An extensive survey of the status quo would obviously be necessary for an in-depth investigation of these issues, but such a comprehensive and in-depth investigation has not been possible since the study has been conducted within the framework of relatively moderate resources.[3] The aim is rather to provide an initial and indicative overview. The paper is centered on the established firms and the main part of the paper is a descriptive account of the product specialization areas, number of firms and employees, and geographical distribution of the firms. Some methodological concerns regarding which firms to include in (and exclude from) the study, are offered in the Appendix. There is secondly a section which discusses the past and current nature of public policy, including the amount of public spending on biotechnology research. The last section presents a summary and tries to assess some strengths and weaknesses of the biotechnology related activities in Norway as of today, before concluding with returning to the issue of whether agglomerated networks is a key in the dynamics of biotechnology also in the case of Norway.

Emergence and current distribution of biotechnology firms

In order to describe the current status of biotechnology firms there is a need for criteria regarding which firms to include in such an analysis. Past overviews of biotechnology in Norway have estimated the number of biotechnology firms in Norway to be between 41 and 110.[4] In contrast to extremely narrow interpretations of biotechnology activities resulting in low total numbers of firms falling within such interpretations, I have selected to use a wide interpretation of biotechnology in this study in the sense of including not only firms which conduct modern biotechnology as their main activity, but also firms which include biotechnology within their secondary activities. The disadvantage of this delimitation is lack of precision, whereas the advantage is that a more comprehensive picture of ongoing activities is achieved.

Topical distribution of biotechnology related firms

Table 1 shows some key characteristics of the 134 firms in Norway which were identified in connection with this study as having modern biotechnology activities as the primary or secondary activity area. In this section we first review the product foci. The firms are divided into six basic product focus areas ranging from pharmaceuticals to bio-chemical production and broad applications, as well as a seventh additional category which consists of firms which focus on both therapeutic and diagnostic applications. The first segment, pharmaceuticals, is rather small both within the biotechnology context as well as when it comes to comparisons with other countries with a significant pharmaceutical industry (e.g. Sweden). In addition the three firms Alpharma, Weifa and Nycomed Pharma focus predominantly on conventional pharmaceutical approaches and not on biotechnology.

[TABLE 1 ABOUT HERE]

In the second segment, therapeutics, we find a considerably higher number of firms, whereas the number of employees is very limited. Space restrictions prohibit describing all the firms in detail, but examples are Algeta (est. 1997, listed in 2007 and 23 employees as of 2006) developing anticancer therapeutics based on alpha particle emitting radionuclides. Biotec Pharmacon (est. in 1985, listed in 2005 and 33 employees as of 2006) conducts research and develops drug candidates within immunology and marine biotechnology focused on immune modulating compounds and enzymes. Lauras (est. 1998 and with 2 employees as of 2006), A-Viral (est. 1986 and with 2 employees as of 2006) and Bionor Immuno (est. in 2000 and with 7 employees as of 2006) all focus on HIV therapies. Clavis Pharma (est. 2001 and with 15 employees as of 2006) is a firm based on so called Lipid Vector Technology (LVT), and relies on strategic alliances with established pharmaceutical firms to commercialize its discoveries.

Intervet Norge supplies fish vaccines and endocrine products. Pronova Biocare has developed the prescription drug Omacor, a lipid regulating Omega-3 based agents which was approved by the US FDA in 2004 (Ault 2005).

In the third segment, which consists of firms active within both therapeutics and diagnostics, we find the firms which have perhaps been most publicized within industry and popular press due to the relatively large size of the segment's firms and their high turnover (see e.g. Mediaplanet 2007). PhotoCure (est. 1997, listed in 2000 and with 31 employees as of 2006) targets selected diseases in dermatology, i.e. research related to skin diseases, and oncology, i.e. cancer related research, and develops and sells devices for these diseases based on photodynamic technologies. Affitech (also est. 1997 and with 31 employees as of 2006) is focusing on human antibody techniques. The majority of its activities are with therapeutic aims, but there are within the firm's portfolio e.g., a "library" and high throughput screening system for antibody discovery which may justify the classification of the firm as integrating both therapeutic and diagnostic aims. Also within this segment are the Norwegian subsidiaries of US corporations GE Healthcare and Invitrogen (Invitrogen Dynal). The former traces its antecedents to Nygaard & Co (est. 1874) and its R&D breakthroughs within X-Ray and ultrasound related reagents (Amdam and Sogner 1994). Parts of this firm evolved into Nycomed Imaging and were then acquired by British Amersham Health in 1997, and subsequently by GE Healthcare. The subsidiary in Norway has 1180 employees as of as of 2006 and continues its focus on reagents. Invitrogen Dynal (est. as Dynal Biotech in 1986 and since 2007 part of Invitrogen) has 175 employees In Norway as of 2006, and was originally founded on the basis of research conducted by the late professor Ugelstad of the University in Trondheim.

The fourth segment, diagnostics and drug delivery, is among the largest in firm count, but is at the same time populated with many small firms. In fact the largest firms within the segment are laboratories providing services to other firms (e.g. Norsk Matanalyse with 53 and as Telelab with 58 employees). Amongst the more specialized firms developing diagnostic devices or procedures we find Axis-Shield, which is headquartered in Great Britain but where major equity stakes are held by the Norwegian pension fund Folketrygdfondet. The Norwegian component of this multinational (Axis) was established in 1985 and acquired by Shield in 1999 for approximately 1 billion NOK. Axis-Shield acquired another Norwegian company, Medinor, in 1999 for 50 million NOK (CGE&Y 2000: 14-15). As of 2006, the Oslo subsidiary of Axis-Shield consists of 18 persons focusing on a delimited research area.[5] Colifast (est. 1999 and with 5 employees) focuses on quick detection of bacteria in e.g. water and foods.

In this overview we have grouped delivery-focused technologies together with diagnostics. These two product categories obviously differ, but the common trait is that both are important tasks auxiliary to therapy itself. The focus on efficient delivery techniques for biopharmaceuticals has intensified since the completion of the human genome project. The effectiveness of delivery techniques is a major influence on the effectiveness of many biopharmaceuticals, since their effects can vary or even be absent according to whether the delivered gene arrives at the targeted cell or not. Within this niche we find e.g. the Photocure subsidiary PCI Biotech, Innovio which focuses on gene delivery methods for DNA vaccines, and Genpoint (acquired by NorDiag in 2007).

[BOX 1 ABOUT HERE]

The fifth segment, bio-informatics, is populated by seven highly specialized bioinformatics firms including Pubgene (established in 2001 and with 8 employees as of 2006), Sencel (est. 2001, 7 employees) and Interagon (est. 2002, 2 employees) which is a spin-off of one of the most renowned ICT firms in Norway, Fast Search and Transfer. The sixth segment, breeding and biobanks, consist of 10 firms including Genomar (formerly Biosoft, est. in 1996 and with 5 employees) is a firm established by academics from the Veterinary College in Oslo. The business idea initially focused on Atlantic salmon, but has since developed into targeting other breeds as well, such as the tropical tilapia fish, and much of its business now is conducted overseas. Additional firms within this segment include Aqua Gen, Bovibank, Geno and Norsvin, where the former focuses on marine species and the three latter on agricultural livestock.

The last segment is bio-chemical production and broad applications, and is thus somewhat heterogeneous in its nature since it spans from industrial waste mechanisms to production of livestock feeds and human alimentation ingredients. Marine biotechnology firms dominate this segment in Norway in terms of firm and employee numbers. Norwegian firms appear to have entered nutraceuticals, i.e. foods claimed to have a medicinal effect on human health, in part because of possibilities for more sophisticated usage of marine material, as well as the potential for exploiting byproducts from fisheries and aquaculture. Aker Biomarine focuses on developing bioactive lipids (fatty acids) for the food and feed industry. Advanced Biopolymers focuses on chitosan-based products, and Firmenich, which was originally a pourely domestic firm but which is now part of a Swiss multinational, focuses on flavor ingredients and nutraceuticals extracted from marine sources. FMC Biopolymer, a subsidiary of the multinational firm with the same name (est. 1999 and with 175 employees in Norway as of 2006), is also predominantly focusing on marine biotechnology in its Norway based activities and acquired as a part of this focus during the 1990s two firms originally spun off from Norsk Hydro. Several other firms specialize in development and production of animal feed from marine bases, such as Akva-Ren, Calanus and Eximo. A minority of firms such as Nutri Pharma and Biolink focus on non-marine ingredients.

The remaining firms within this heterogeneous segment include Diatec producing monoclonal antibodies for use in medical research, and several firms focusing on industrial applications. They include Biosentrum (est. 1997), which is a contract research and manufacturing firm within fermentation and has had projects regarding e.g. biopolymers for secondary oil extraction, biosurfactants for use in bioremediation, fish vaccines and organic acids, and BioProtein (est. 2007 but in many ways a re-establishment of another firm est. in the 1980s) extracting protein from natural gas.

Pattern of emergence of biotechnology related firms

Having described segment by segment as for activities we will describe the pattern of emergence in some detail while trying to distinguish not only between segments, as above, but also between marine biotechnology and other applications.

[FIGURE 1 ABOUT HERE]

[TABLE 2 ABOUT HERE]

[FIGURE 2 ABOUT HERE]

38 percent of the firms were established before 1996 (Fig. 1), although there is some discrepancy between segments as for the ratios of pre-1996 establishments (Table 2). Within the pharmaceutical and therapeutic/diagnostic segments all seven firms were established prior to 1996. Moreover and as mentioned in the preceding section, for one of these firms (GE Healthcare) the predecessor dates back to Nygaard & Co (est. 1874). When it comes to bio-production and broad applications the pre-1996 firm population of 20 firms stands out, and may be explained by a considerable ratio of firms within marine biotechnology which already existed prior to 1997 within e.g. fish processing or aquaculture related feed production. One prominent example is the firm Pronova Biocare, which was established in its present form in 1992, but builds on a predecessor established in 1917. Within diagnostics there were indeed 11 firms already established by 1996, but the high increase in the period 1998-2000 with 17 additional firms is noteworthy. One explanation for this sharp increase is the foreign acquisition of Nycomed Imaging in 1997 mentioned in the preceding section and the subsequent decision to establish or participate in start-ups by several former Nycomed Imaging employees (Grønning et al 2006). Still another category with a strong pre-1997 existence is breeding and biobanks. Two of the seven pre-1997 firms are, however, agriculture related firms specializing in cattle and pork insemination and breeding programs. As for the two remaining segments we see from Table 2 that therapeutics is spread out rather evenly, whereas bioinformatics is of a relatively recent origin.

Turning now to the distribution between marine biotechnology ("Blue biotechnology") and other fields the situation is heavily influenced by the phenomenon mentioned in connection with the emergence of bio-production and broad application firms, in other words the pre-1997 existence of fisheries and aquaculture related firms (Fig. 2). There is a total of 49 firms categorized as "Blue", and 20 of these are pre-1997: 11 within bio-production and broad applications, five within breeding/biobanks, and three within therapeutics (only three firms). As for the period 1997-2007 the internal distribution of “Blue” firms is led by 23 firms within bio-production and broad applications, something which perhaps is interpretable by additional actors seeing the possibilities in the development of fish oils based ingredients and additives. The remaining six firms in the 1997-2007 period are within the therapeutics segment.

Geographical distribution of firms

As for regional concentration within the Norwegian biotechnology industry, the Eastern part of Norway stands out as the major agglomeration with 74 firms (Fig. 3), at the same time as the proportion of “Blue” firms is lowest here. Although a majority of firms (54 firms) are located in Oslo city or its environs (the municipalities Ås, Bærum, Skedsmo and Asker), it should be noted, however, that the other 20 firms in the Eastern part are located at distances of up to ca. 150 kilometers from Oslo. Western and Northern Norway has 27 and 21 firms respectively, and the ratio of “blue” firms is markedly higher in the Northern part. This is indeed the region where aquaculture and fisheries has the longest traditions, and the higher ratio of non-“blue” firms in the Western part is attributable in part to the medical research being conducted at the University of Bergen and Haukeland Hospital. The central part where the science and technology university of Norway is located has, perhaps surprisingly, very few firms. One should note, however, that there in the past have been spin-offs from this university (e.g. the current Invitrogen Dynal) where the actual firm was established elsewhere.

[FIGURE 3 ABOUT HERE]

As for networks and organizations there exists at the national level a Norwegian Bioindustry Association (est. 2001), which is part of the Employers’ Federation division for process industries. The Association holds regular meetings (usually held in Oslo) about trends within the industry and acts as a lobbying organization. Another organization called Biomarine Forum (i.e. Biomarint Forum) tries to coordinate actors within the at biomarine business cluster in order to stimulate cooperation between sectors and improve framework conditions for the industry, and the Norwegian NanoMedicine Network (est. 2007) aims to gather research, industry and public administration within the nanomedicine field..

At the international level, Medcoast Scandinavia (est. 2004) [6] supports the regional Gothenburg and Oslo biomedical sector in becoming "a leading biomedicine region in Europe" (MedCoast Scandinavia 2007: 3). The organization collaborates in turn with the local GothenburgBio and OsloBio (see below). Some Norwegian organizations are also engaged in another international network, Scanbalt.[7]

OsloBio aims to contribute through marketing, initiating and facilitating development projects, and supporting international collaboration. Oslo Teknopol acts as the secretariat for Oslo Bio. Oslo Bio focuses on marine life science, cancer therapy and diagnostics and wireless life science. The cancer therapy and diagnostics area is handled by its own organization called the Oslo Cancer Cluster (OCC). As of 2007, the OCC includes as members 20 local biotech firms including e.g. Affitech, Algeta and Photocure, in addition to six pharmaceutical firms including the domestic ones and foreign firms with representation in Norway, TTOs from the University of Oslo and two national hospitals located in the Oslo area, and policy organizations such as Innovation Norway and MecCoast Scandinavia (OCC 2007).[8] The overall goals of the OCC seem at present to be somewhat vague, although the level of ambition is high in stating that the cluster is "to become the most attractive Research Based Industrial Cluster in Europe for Cancer Diagnostics and Treatment Innovations by

2015“ (OCC 2007). One step towards this goal is to apply during 2007 for Research Council funding as a Norwegian Centre of Expertise (OsloBio 2007). In the Eastern part of Norway there is in addition a network called BioInn based in the inland region of Norway approximately 100 kilometers from Oslo, consisting of regional colleges and firms that focus mainly on agricultural biotechnology.

The Western (Bergen, Stavanger and the North-west coast) area has a biotechnology network mainly consisting in organizing regular meetings that focus on marine biotechnology entitled Meeting Place Marine (i.e. Møteplass Marin). Two Bergen based biomedical firms also are affiliated with the OCC.

In the North (mainly the city of Tromsø) there has since 2002 been a “Biotechnology in Tromsø” group, discussing the premises of the biotechnology industry in this part of the country. The ten members represent the biotechnology industry, research, the public support system and regional authorities. As a prolongation of this group a project entitled Biocluster North (i.e. Bioklynge Nord) or Forum for Biotechnology and Aquaculture (i.e. Forum for bioteknologi og havbruk), has been in action as part of a larger program funded by SIVA and the research councikl of Norway 2004-2006 (Normann 2007). MabCent (Marine bioactives & drug discovery), received status as a research-driven centre innovation centre in 2006 (FKD 2006) and is expected to serve as a nexus for increased networking activities in the region as well (Normann 2007). There seem to be no comparable organizations in the central (Trondheim) area, apart from meetings and seminars taking place at the university in Trondheim.

Performance

The distribution of biotechnology firms in Norway among industry segments discussed earlier should be kept in mind when assessing indicators of firm performance. The greatest need for protection in the form of patenting is in the therapeutics and therapeutics/diagnostics segments. Diagnostics is also an area in which IPR in the form of patents is important, whereas methods for ingredients production may in some cases rely on generally available techniques. In addition and regardless of their segment, many firms are relatively recent in origin, and it is for these too early to expect a high number of patents or commercialized products.

PCT (Patent Co-operation Treaty) patenting data indicate that Norway's share (0,3 percent) of biotechnology patents for the year 2003 is slightly lower than Finland's (Fig. 4). As of 2003, Denmark and Sweden have larger biotechnology industries and higher patenting levels. On average, Canada, Denmark, and the United States are among the countries in the world that apply for more patents in biotechnology than in other fields. For Denmark and Canada, biotechnology represented more than 10% of all patents filed under PCT (van Beuzekom and Arundel 2006: 20).[9]

[FIGURE 4 ABOUT HERE]

Another indication of the viability of Norwegian biotechnology is the fate of older biotechnology startup firms in Norway, specifically, the 41 firms existing as of 1999 that were listed by van Beuzekom (2001: 88). As of 2007, 35 of them still exist, one has been dissolved, four are still registered as firms but do not have any employees and are dormant at best, whereas one seems to have merged with another small firm.[10]

Trends in the environment of biotechnology-related firms

Trends in venture capital markets

The OECD has observed that there have been relatively “low levels of risk capital in Norway as well as a scarcity of entrepreneurs” (Baygan 2003), and explained this phenomenon in macroeconomic terms including “large public holdings, very small pension, insurance and other financial entities, and low levels of evenly-distributed household wealth” (ibid.). In 2005, the share of private equity investments in Norway was 0,24 percent of GDP, compared to 1,24 percent in Denmark, 0,86 percent in Sweden and 0,47 percent in Finland, whereas the average for Europe was 0,40 percent (EVCA Yearbook 2006, as cited in NVCA 2007). Restricting the comparison to biotechnology-related venture capital as a percentage of GDP (Table 3), Norway surpasses both amongst others Sweden, Denmark and Finland, but is far behind the Unite States.

[TABLE 3 ABOUT HERE]

Most Norwegian VC is invested domestically. In the 2000-2002 period only about 16% of the total VC funding went offshore,[11] mostly to the United States (56 percent) and Sweden (17 percent) (Baygan 2003). At the same time, international investors played a minor role in the Norwegian VC market. During 1997-2001 they contributed about 6 percent, compared to the European average of approximately 50 percent of funds raised being cross-border investments (EVCA, 2002 as cited in Baygan 2003).

[BOX 3 ABOUT HERE]

The establishment and growth of various forms of organizations related to the VC sector is relatively recent. The first professional venture capital firms in Norway emerged at the beginning of the 1980s, but it was not until 2001 that the Norwegian Venture Capital Association (NVCA), which is in turn a member of the European Venture Capital Association (EVCA), was established. As of 2005 the NVCA had 20 primary members including and 21 associated members including the largest seed investor Statoil Innovation and the state owned indirect investment fund Argentum (see Box 3). The number of "Business Angels" networks has risen from none in 2000 via one in 2001 and seven by 2004 (EBAN 2007).

The sectoral distribution of Norwegian venture capital investment is dominated by resource extraction industries and ICT. Dedicated biotechnology investments accounted for only five percent of all Norwegian VC investments in 2005, compared to 20 percent for medical technology related activity (which might indeed include some biotechnology related activity as well), 15 percent for IT/Telecom, and 21 percent for energy (NVCA 2006). This inter-sectoral distribution differs from those observed elsewhere in the Nordic region: Roughly 30 percent of all Nordic VC investments (which are dominated by Swedish VC funds) in 2005 were made in biotechnology companies, whereas energy accounted for only 2 percent. IT and telecom are, perhaps not surprisingly, large in Finland (24 percent), whereas Danish VC investments focus heavily on biotechnology, IT and telecom investments (Sørheim et al 2006: 27).

General institutional environment

This section reviews the general institutional environment, public funding of biotechnology R&D, and the role of public policy in generating biotechnology-related business activities. Box 4 shows selected biotechnology-related events in these regards. During the late 1970s and early 1980s, a number of public forums and study groups in biotechnology were established under official sponsorship in Norway in response to news of dramatic scientific advances in the field. This process was probably not very different from many other European countries, but in the Norwegian case the process led to an institutional distinction between gene technology as applied to living organisms (the Gene Technology Act of 1993) and biotechnology as applied within medicine (Biotechnology Act of 1994). The distinction has been retained within the latest revision of the legal framework (2006-2007), with the government proposing a revision of the Biotechnology Act that allows for research on embryonic stem cells. If passed, the new legislation which will come up for voting in parliament during 2007 would relax somewhat the regulatory environment for biotechnology research.

[BOX 4 ABOUT HERE]

One area of continued controversy, however, concerns the commercial handling of genetic information obtained from the population. The 2003 Act on biobanks restricts access to the material stored in Norwegian public biobanks containing human material, at the same time as public research and business alike sees great possibilities in scientific and commercial exploitation of these data equal or surpassing those of Iceland's due to the greater volume of data and possibilities of coupling information to other registries (Olsen 2006). Norway does, however, have a liberal attitude towards conventional clinical tests of drug candidates, and the number of clinical tests being performed in the country each year is comparatively high (Dobos et al. 2004). An institutional issue affecting the level of attractiveness for biotechnology firms to locate in Norway is the relationship to academic organizations. Legislation arguably has improved the biotechnology business climate. The 2002 University

Act amendments gave universities and colleges the primary responsibility for facilitating the exploitation of research, and Norwegian universities subsequently established technology transfer offices (TTOs). Another amendment transferred the rights to inventions made by employees from employees to their employing organizations (Aanstad et al. 2005: 3). These two changes are obviously not specific to biotechnology, but have brought Norway into line with other countries in Europe when it comes to potential academia – business collaboration.

Level of public funding

Norwegian biotechnology research programs have grown significantly in numbers since 1998, but have, with the exception of the FUGE program, been small in size (Box 4). This explains in part the low standings of Norwegian public research expenses within biotechnology in the most OECD survey referring to the year of 2003 (van Beuzekom and Arundel (2006: 19). When it comes to the ratio of biotechnology R&D conducted within the public sector (universities and PROs) in relation to the amount of R&D expenses within private firms, the percentage is extremely high in the case of Norway, at least through 2003. Spain and Korea, for example, approach the level of Norway, but these two nations are still quite far behind (ibid.). At the same time the absolute amount of public funding for biotechnology R&D in Norway is moderate by international comparisons, and lower than Finland, New Zealand and Denmark (the actual situation for Sweden is unknown). Compared to the ca. 75 percent of the R&D being financed by public means in Norway in 2003, the corresponding figure in 2005 was more than 80 percent (ca. 960 million NOK). [12] Biotechnology R&D expenditures by the public sector were 831,6 million NOK, increasing to 1, 179 billion NOK in 2005. The biotechnology R&D share of total public R&D was six percent in 2003, rising to approximately seven percent in 2005 (Sundnes and Sarpebakken 2007).

Human medicine and biopharmaceuticals were the largest fields of Norwegian public funding for biotechnology R&D in 2003 and in 2005. The University of Oslo and its associated hospitals are by far the largest single academic recipient of public biotechnology R&D funding, accounting for more than half of the expenditures. Its spending nearly doubled during this two-year period, with a majority of the increase accounted for by the University's hospitals (Sundnes and Sarpebakken 2005, 2007). There was an increase of 350 scientists participating in biotechnology research in the public sector between 2003 and 2005, producing a total of 1800 scientists as of 2005 (ibid.). International comparative data for 2005 are not available, but the increased Norwegian public funding may well have raised Norway's rank in international comparisons relative to 2003. Nevertheless the dominance of public funding within overall Norwegian R&D spending in biotechnology is likely to remain unaltered for the near future.

Discussion and conclusion: Peripheral advantage, or just periphery?

I conclude this survey by summarizing in the form of a SWOT (strengths, weaknesses, opportunities and threats) format at the level of Norwegian commercial biotechnology activities, and then providing some reflections on the overall current and possible future state of biotechnology in Norway, drawing on the framework proposed by Niosi (2003) regarding agglomeration benefits.

A tentative assessment of the situation

Strengths include the scientific and commercial success of several firms, which may draw increased attention to them and other new entrants. Patenting seems to be increasing, and some products have been launched or are in the process of being launched. Several highly publicized Norwegian firms within diagnostics and drug delivery are believed to have considerable growth potential, as are others in therapeutics and marine biotechnology. These successful examples may serve as models for other firms considering entry into these segments of biotechnology. Norway also has a dominant group within diagnostics that builds on past strengths in medical devices. The examples of Photocure, DiaGenic and PCI Biotech also point towards a possible new Norwegian capability to combine predominantly academic knowledge about diseases and their diagnosis or treatment with commercially oriented electronics, in some cases reagents, and in other cases, informatics.

There is considerable health-related biotechnology activity in the Oslo area. The Oslo concentration may also prove capable of interacting with Gothenburg-based firms and PROs, as well as with other firms in the Oslo region. The total amount of venture capital potentially available is considerable, and has a highly developed tradition for administering clinical tests for the pharmaceutical industry.

Weaknesses include the lack of large Norwegian pharmaceutical firms, although this gap is in part compensated for by a strong Norwegian presence of several multinational firms such as AstraZeneca and GSK, that pursue both marketing and clinical tests in Norway. The large indigenous companies within the Norwegian innovation system have in recent years concentrated on their core competencies and, with some exceptions (see below) decided not to invest in other areas. The most prominent example of this is Norsk Hydro, which was involved in the start-up and expansion of several biotech firms. Norwegian venture capital investment is concentrated in non-biotechnology areas. There has in the past allegedly been little interaction within the largest group of firms focusing on diagnostics (CGE&Y 2000), although this seems to be changing with the advent of thematic and regional umbrella organizations.

Opportunities include the recent interest in and strengthening of marine biotechnology basic research, such as the recent establishment of the Akvaforsk research consortium and the new centre for this purpose in Tromsø. State controlled biobanks may turn out to be the basis for future commercial activity. Competencies within diagnostics and information from biobanks might be combined into ingenious drug delivery technologies. Already in 2000 the expectations based on lessons from the HUGO project have led to predictions about individualized pharmaceuticals (CGE&Y 2000: 6), and this is a new area in which Norwegian biotech could play a role. Within the production-based segment there are ample possibilities of expanding as well as refining the product lines, as companies like Aker Biomarine is doing. This firm is incidentally also an exception form the trend of large enterprises abstaining from engaging in a field like biotechnology, in that it is part of the large Aker Corporation.

Although geographically dispersed among Oslo, Bergen, Trondheim and Tromsø, the cultural and institutional proximity of firms as well as the tradition of collaboration within Norwegian business may provide opportunities for enlarged networks that extend beyond the clustering at any specific location. The inclusion of Bergen based NorDiag in the Oslo Cancer Cluster is an example of this approach.

Experience in “demand driven” (Goldfarb et al. 2001) collaboration might have potential for emulation by other firms especially within the large diagnostics and drug delivery segment. By generating additional values or competences at the Norwegian location, the risk for “hollowing out” (see below) might to a certain degree be countered. One case in point may be the example of DiaGenic, which has developed a technology that could itself be transferred elsewhere, but where the development process for this technology has relied on "demand driven" collaboration between technically and scientifically competent staff within the firm and scientific staff at public organizations with in-depth knowledge of specific therapeutic areas. Such a strong bilateral relationship may not be easily transferred, and this type of industry – academia collaboration, which differs from the conventional "supply driven" (ibid.) form.

Threats include fragility of the established network. Successful innovation achieved in peripheral locations such as Norway may somewhat paradoxically result in the movement from Norway to foreign sites of key personnel or technical capabilities if the technology is deemed as useful at the other location. The most attractive firms, technologically speaking, may thus be vulnerable to "hollowing out" processes triggered by foreign acquisitions of the whole firm or parts thereof, although continued activities in a wider sense through establishment of other, smaller firms within a similar technological specialization area seem to have made up for the personnel reductions within some foreign owned firms.

An additional, potential threat is that the historical record of innovation policy in Norway is characterized by a lack of understanding at the policy level of the heterogeneous nature of commercial opportunities within biotechnology. Biotechnology firms and start-ups are referred to in most policy documents as firms that uniformly face long development times, high risk factors, and large capital needs (e.g. therapeutics oriented firms like Biotec Pharmacon). In fact, however, a majority of Norwegian biotechnology firms belong to other segments, such as diagnostics and bio-chemical. There is thus a certain risk that overall sectoral policies will be designed for only one type of firm, rather than developing a differentiated policy framework

Public policies also have assumed that Norway had a special comparative advantage within marine biotechnology, a strength which in turn was perceived to be based on past marine experience like fisheries and aquaculture. There are indeed correlations between these fields, but vast efforts in other fields additional to the recent initiatives mentioned above seem to be necessary if one wants to develop marine-biotechnology based applications within drug development, for example.

The small number of Norwegian science and technology graduates combined with limited immigration within these fields may pose a threat to the expansion of public and business R&D efforts alike.

The policy initiatives have, among other things, focused on past and present research strength in fields such as oncology (MedCoast 2007), where Norwegian researchers appear to be much stronger than in fields such as biopharmaceuticals (van Beuzekom 2001: 15; Enzing et al. 2006: 106). To maintain and strengthen Norway's reputation as a specialized high-level oncology research center will require continued excellence in publication and research performance to exploit increased funding opportunities and overcome the negative publicity associated with alleged weakness within biopharmaceuticals.

In Norway, policy measures and institutional frameworks have been subject to some change and instability within the biotechnology sector, and this may have acted as a disincentive for private investment in this industry. Specialized investors are still largely absent, with the recent exception of the new investment fund Sarsia Innovation.

Conclusions

As concluding remarks we will now return to the proposal by Niosi (2003) regarding that "networks of DBFs, venture capital firms, large corporations and research institutions are key in the dynamics of biotechnology". We have seen that large enterprises are to a significant extent absent from the Norwegian context. However, they are indirectly present in the form of representation, such as e.g. foreign pharmaceutical firms such as AstraZeneca and GSK participating in the Oslo Cancer Cluster, and at least one large domestic firm is involved in biotechnology. Nevertheless, the general absence of large domestic firms underscores the importance of initiating and maintaining networking activities such as those supported by Møteplass Marin, BioKlynge Nord, OsloBio and Oslo Cancer Cluster. The Niosi hypothesis is also open to question concerning the size and extent of the networks that are allegedly needed in order to deserve the label of network. In the Norwegian case one could discuss whether the minimum level of firm population has been reached at the national level, and whether all the four main Norwegian locations of Oslo, Trondheim Bergen and Tromsø should or should not be seen in connection as one network or as four separate networks. In the Oslo area case, the relationship to Gothenburg and, possibly, even further towards the Øresund region is also a possibility firms could consider for seeking customers or collaboration partners.

In the case we cannot discern a network (or four networks) in the Niosi sense, the Norwegian experience is perhaps an interesting example of an alternative organizational mode. One element in the set-up of the Norwegian context is the significant presence of marine biotechnology, albeit perhaps not as dominant as one could expect based on policy predictions.

Also, although the medical component is strongly present in the Norwegian case, the auxiliary segment (diagnostics and drug delivery) is more prevalent and does not necessarily have the same immediate needs as therapeutics for geographical proximity to venture capital firms and science centers. This may also be a segment which is especially conducive towards demand driven collaboration forms, e.g. within engineering-oriented solutions within diagnostics. Similarly, demand driven – and not necessarily geographically proximate- collaboration forms may be more relevant than supply driven collaboration forms within biochemical production. Thus, perhaps in conjunction with the advances of biotechnology itself and increased heterogeneity of biotechnology related firms, the forces conducive to agglomeration being weakened? It might then after all be possible to foster a viable biotechnology industry in a location remote from the science based centers of the world with limited firm population, as well as with limited size of the domestic research organizations.

A follow-up of this question will, however, have to be an issue for further research focusing on the Norwegian experience. The review has shown that most important events occurred very recently, from the mid-1990s onwards. The number of new firm establishments grew from 1997 onwards, and the emergence and subsequent consolidation of the biotechnology industry in Norway is therefore at a very early stage, although there are some indications of path dependence in the sense of building upon past strengths and capabilities. This phenomenon is discernible especially in connection with the emergence of advanced diagnosis and drug delivery techniques and of photo-therapeutic solutions, all of which have roots back to previous achievements within Norwegian industry based on reagents and engineering. Also, the current presence of a large number of firms within nutraceuticals would have been unlikely without the past capabilities in fisheries and aquaculture.

The emerging Norwegian biotechnology industry is more difficult to position within path dependencies in terms of the taxonomy in Wicken (2007) that described a set of layers consisting of sectoral groups and their geographical and institutional surroundings that range from small businesses focused layers to heavy industries focused layers. Large parts of the contemporary biotechnology industry in Norway have elements in common with high technology engineering, and in the case of marine biotechnology, there are commonalities with the natural resources extraction tradition. Moreover, the recent emergence of biotechnology firms has occurred simultaneously with the new the types of relationships the firms have developed with academic organizations, as well as simultaneously with the development of a venture capital market. Taking these three together, we may perhaps rather talk of this set of developments as a kind of "path creation" (Garud and Karnøe 2000; Schienstock 2004). That is, we obviously do not know at present whether and how this part of the Norwegian economy will develop into a dominant position, but we might be witnessing the creation of an emergent path that will be characterized by a rather unique kind of peripheral advantage.

Notes

1 Biotechnology is usually defined as "the application of scientific and engineering principles to the processing of materials by biological agents to provide goods and services" (van Beuzekom and Arundel 2006: 14), whereas “modern biotechnology” refers to the applications emerging form scientific discoveries at the genome level during the 1970s (cf. Queré 2004).

2 Marine biotechnology is, as noted by Biobridge Ltd. unlike other areas of biotechnology in that it is defined in terms of its source material, rather than the market it serves (Biobridge Ltd, 2005, as cited in Aslesen 2005: 9). ESF's "vision for the 21st century is that marine biotechnology will apply advanced tools from molecular biology and information technology to a carefully selected suite of marine habitats and organisms representing the total diversity of marine systems, in order to obtain novel genes and processes that can be turned into new products and approaches for the benefit of industry, biomedicine, and the sustainable use and management of the world’s ocean” (ESF 2001: 4), and the foundation divides into the five different marine biotechnology research and business sub-areas developing novel drugs; producing diagnostic devices for monitoring health; discovering new types of composite materials, biopolymers and enzymes for industrial use; ensuring safety of aquaculture and fisheries; and providing new techniques for management of marine environments; (ibid.: 6, with order altered; see also Grønning et al. 2004).

3 Observations serving as a foundation for the analysis were obtained in connection with a one year project funded by the Research Council of Norway in 2005 (Dobos et al 2004; Grønning et al. 2004; Grønning et al. 2006), whereas the current paper itself is based on additional non-funded research during a half year period in 2006-2007.

4 The estimates are 41 firms (Critical I 2006), 85 (Research Council of Norway according to Berntsen and Dalen 2004), ca. 75 firms (EBN 2006), and 110 (Marvik 2005; NFR 2007). Critical I (2006) itself operates with 41 firms, whereas a more detailed overview identifying the firms says 42 firms (Hodgson 2006).

5 Critical I (2005) reports a ca. 50 persons in staff.in 2003.

6 MedCoast Scandinavia started already in 1995 through a joint venture agreement , established in April 2002 as a project, established as an independent member organization in November 2004, and began operating on the 1st of January 2005 (MedCoast Scandinavia 2007: 3-4)

7 These are BioInn (see below) and Innovation Norway.

8 The local firms which are members are Affitech, Algeta, Alpharma, A-Viral, Axis-Shield, Biomolex , CancerCure, Clavis Pharma, DiaGenic, Lauras, Lytix Biopharma, Mole Genetics, NorChip, Nordiag, Optinose, PCI Biotech, PhotoCure, PubGene, Photosense, and Drug Discovery Laboratory (DDL); the pharmaceutical firms are AstraZeneca, Bristol-Meyers Squibb, GlaxoSmithKline, Merck (MSD), Pfizer and Roche, and the TTOs and policy organizations are Birkeland Innovasjon affiliated to the University of Oslo, MedCoast Scandinavia, Medinnova (the National Hospital TTO), Innovation Norway , Oslo Teknopol , IKS , and The Norwegian Radium Hospital Research Foundation (OCC 2007).

9 This is also the case for and Belgium (OECD 2006: 20).

10 There are actually 44 firms in the list presented by van Beuzekom (2001: 88), but two are established pharmaceutical firms and one is not conducting biotechnology research and have been excluded form the mapping.

11 Note that we are still dealing with the VC market in isolation, and thus not including the overseas stocks and bonds invested in by the Petroleum Fund.

12 It should be noted that the estimates on business R&D are not directly comparable between 2003 and 2005, since statistics until 2003 divide between marine R&D and biotechnology R&D, whereas starting in 2005 marine biotechnology as a sub-field is to be classified as biotechnology.

References

Aanstad S., P. Koch and A. Kaloudis (2005*).* *European Trend Chart on Innovation: Annual Innovation Policy Trends and Appraisal Report Norway 2004 – 2005*, Brussels: European Commission.

Aldridge, S. (2005). "Blue Biotech Puts Norway on the Map: Prospecting for Commercial Opportunities in Marine Environments", *Genetic Engineering & Biotechnology News*, Oct 15 2005 (Vol. 25, No. 18).

Amdam , R. P. and K. Sogner (1994). *Wealth of Contrasts: Nyegaard & Co.-A Norwegian Pharmaceutical Company, 1874-1985*. Oslo: AdNotam Gyldendal.

Argentum (2005). *Argentum Årsrapport 2005*. Oslo: Argentum.

Aslesen, H. W. (2005). "Commercialisation of Knowledge. The case of Norwegian Marine Biotechnology", paper to *The 5th Triple Helix Conference*, Turin-Milan, 18-21 May 2005.

Ault, A. (2005). "Prescription omega-3 fatty acid formulation approved", *OB/GYN News*, Jan 15, 2005.

Bagchi-Sen, S. (2007). "Strategic Considerations for Innovation and Commercialization in the US Biotechnology Sector", *European Planning Studies*, 15:6, 753 – 766.

Bartholomew, S. (1997). "National systems of biotechnology innovation: Complex interdependence in the global system", *Journal of International Business Studies*, Vol. 28, pp. 241-66.

Baygan, G. (2003), *Venture Capital Review Norway*, STI Working Paper 2003/17 Industry Issues. Paris: OECD.

Berntsen, W. and E. Dalen (2004). *Foresightanalyse bioteknologi: Rapport utarbeidet for Norges Forskningsråd*. Oslo: MMI Unero.

Biomarint Forum (2007). www.biomarintforum.no accessed July 2007.

Brink, J., L. Dahlander and M. McKelvey (2007). "Developing Capabilities: An Analysis of Biotechnology in two Regions in Australia and Sweden", *European Planning Studies*, 15:6, 727 – 751.

CGE&Y (2000). *Næringsrettet bioteknologi i Norge: Statusrapport*. Oslo: Norges forskningsråd.

Critical I (2005). *Biotechnology in Europe: 2005 Comparative study*. Critical I.

Critical I (2006). *Biotechnology in Europe: 2006 Comparative study*. Critical I.

DiaGenic (2007). DiaGenic home page www.diagenic.no last accessed 2 May, 2007.

Dobos, E., T. Grønning, M. Knell, D. S. Olsen and B. K. Veistein (2004). *Norway Vol. 1: Biopharmaceuticals*. Report submitted to the OECD in the series ‘Case studies in innovation’ (DSTI/STP/TIP(2002). Paris: OECD.

EBAN (2007). *European directory of business angel networks in Europe*, Version 2 January 2007. Brussels: EBAN.

EBN [EuroBiotech News] (2006). “Focus on Norway: Major investments renew optimism”, *EuroBiotech News* 5(1-2), 40-43.

Eliasson, G. (2000). “Industrial Policy, Competence Blocs and the Role of Science in Economic Development", *Journal of Evolutionary Economics*, 10: 217-241.

Ernst & Young (2000). *Convergence: The Biotechnology Industry Report*. Ernst & Young.

FKD (2006*). Pressemelding Nr.: 49/2006*. Oslo: Fiskeri- og kyst-departementet.

Garud, R. and P. Karnøe (2000). *Path Dependence and Creation*.. Mahwah/London: Lawrence Erlbaum Associates.

GEN [Genetic Engineering News] (2007). “DiaGenic ASA 2007 Entrepreneurial Company of the Year Award on DiaGenic ASA in the European Molecular Diagnostics Market”, *GEN*, March 12, 2007.

Goldfarb, B., M. Henrekson and N. Rosenberg (2001). *Demand vs. Supply Driven Innovations: US and Swedish Experiences in Academic Entrepreneurship*. Unpublished manuscript.

Grønning, T., with E. Dobos, M. Knell, D. S. Olsen, I. D. Frogner and O. A. Johansson. (2004). *Norway Vol. 2: Marine biotechnology*. Report submitted to the OECD in the series ‘Case studies in innovation’ (DSTI/STP/TIP(2002). Paris: OECD.

Grønning, T., E. Dobos, M. Knell, D. S. Olsen and B. K. Veistein (2006). “Norway”, in Enzing, C. M. (ed.) *Innovation in Pharmaceutical Biotechnology: Comparing National Innovation Systems at the Sectoral Level*. Paris: OECD, 2006.

Hernes, T., P. I. Olsen and A. Espelien (2004). *Jordbruksvaresektorens muligheter i sjømatbasert næringsutvikling*. Forskningsrapport 3/2004 Handelshøyskolen BI Senter for samvirkeforskning. Sandvika: Handelshøyskolen BI

Hodgson, J. (2006). “Europe must do bigger: Critical I’s 2006biotechnology comparative study”, presented to the *Norwegian Bioindustry Forum*, 13th June 2006.

Kallerud, E. (2004). “Science, Technology and Governance in Norway Case study no 1: Biotechnology in Norway”, *STAGE (Science, Technology and Governance in Europe) Discussion Paper 15*.

Lönneborg, A. (2007). “DiaGenic: Funksjonell genomforskning og potensialet for næringsutvikling”, talk to *Norwegian Bioindustry Forum*, 24 April, 2007.

Louët, S. (2004). ”Norway goes private to develop biotech”, *Bioentrepreneur* (http://www.nature.com/bioent/) 27 May 2004.

Mabit (2002). *Mikroskopiske sjanser og andre muligheter med marin bioteknologi* . Tromsø: Mabit- programmet.

Marvik, O. J. (2005). *Norwegian Life Science Industry: Overview and Status. Extracts and comments to "NorBioBase", a national database for the biotech industry*. Oslo: O.J. Marvik, 4bio AS, on behalf of Innovation Norway.

MedCoast Scandinavia (2007). *MedCoast Scandinavia 2006*. Gothenburg and Oslo: MedCoast Scandinavia.

Mediaplanet (2007). *Bioteknologi*, Vol. 1, February 2007.

Mitra, Jay (2000). ”Making connections: Innovation and collective learning in small businesses”, *Education and Training*, 42(4/5), 228 – 237.

NFR (2007). "Satser på bioteknologibedrifter ", *FUGE nyhetsbrev* nr. 1/2007.

Nightingale, P. P. M. (2004). "The myth of the biotech revolution," *TRENDS in Biotechnology*, 22(11): 564-569.

NHD (1998). *Nasjonal strategi for næringsrettet bioteknologi*. Oslo: NHD.

NHD (2006). Stortingsmelding nr. 13 (2006-2007): Et aktivt og langsiktig eierskap. Oslo: NHD.

Niosi, J. (2003). "Alliances are not enough explaining rapid growth in biotechnology firms", Research Policy, 32, 737–750.

Normann, A. K. (2007). Connecting people- Towards an industrial cluster. The north Norwegian marine biotechnology industry. NORUT Samfunnsforsking AS Rapport nr 2/2007.

NVCA (annual). *Analyse av aktivitet i der norske venture- og private equity markedet* (2002, 2003, 2004) & *Bransjenalyse Venturemarkedet*. Oslo: NVCA.

NVCA (2007). *Stortingsmelding om innovasjon – invitasjon til å komme med synspunkter: Private Equity bransjen som pådriver for innovasjon og næringsutvikling*. Oslo: NVCA.

OECD (2006). *Compendium of patent statistics 2006*. Paris: OECD.

Olsen, C. R. (2006). "Skreddersydd medisin", *Horisont* 3/2006, 24-33.

Owen-Smith, J., M. Riccaboni, F. Pammolli and W.W. Powell (2002). "A comparison of U.S. and European university-industry relations in the life sciences", *Management Science*, 48(1):24–43.

Pisano, G. (2000). “In Search of Dynamic Capabilities”, in G. Dosi, R.R. Nelson and S.G. Winter (eds.) *The Nature and Dynamics of Organizational Capabilities*. Oxford: OUP.

Powell W.W., K.W. Koput and L. Smith-Doerr (1996). "Inter-organizational collaboration and the locus of innovation: Networks of Learning in Biotechnology", *Administrative Science Quarterly*, 41, pp. 116-145

Queré, M. (2004). “The post-genome era: Rupture in the organization of the life science industry?”, McKelvey,M.; A. Rickne; J. Laage-Hellman (eds.) *The Economic Dynamics of Modern Biotechnology*. Cheltenham: Edward Elgar Publishing, pp. 76-98.

RMV (Regjeringsutvalget for marin verdiskaping) (2003). *Forslag til strategi for kommersialisering av marin bioteknologi*. Oslo: Fiskeridepartementet.

Sarsia Innovation (2007). Sarsia Innovation home page http://www.sarsia.com/ last accessed 28 April, 2007

Schienstock, G. (2004). “From path dependency to path creation: A new challenge to the systems of innovation approach”, in Schienstock, G. (ed.) *Embracing the Knowledge Economy: The Dynamic Transformation of the Finnish Innovation System*. Cheltenham, UK: Edward Elgar, pp. 3–27.

Senker, J. (1996). “National systems of innovation, organizational learning and industrial biotechnology”, *Technovation*, 16, 219–230.

Sundnes, S. L. and B. Sarpebakken (2005). *Bioteknologisk FoU 2003: Ressursinnsats i universitets- og høgskolesektoren og instituttsektoren*. NIFU Report 7/2005. Oslo: NIFU.

Sundnes, S. L. and B. Sarpebakken (2007). *Bioteknologisk FoU 2005: Ressursinnsats i universitets- og høgskolesektoren og instituttsektoren*. NIFUSTEP Report 8/2007. Oslo: NIFUSTEP.

Sørheim, R., L. Ø. Widding & K. Havn (2006). *Nordic Private Equity: An industry analysis*. Oslo**:** Nordic Innovation Centre.

Teknoinvest (2007). Teknoinvest home page http://www.teknoinvest.no/ last accessed 28 April, 2007

van Beuzekom, Brigitte (2001). *Biotechnology Statistics in OECD Member Countries: Compendium of existing national statistics*. OECD Science, Technology and Industry Working Papers 2001/6. Paris: OECD.

van Beuzekom, Brigitte and Anthony Arundel (2006). *OECD Biotechnology statistics – 2006*. Paris: OECD.

Wicken, Olav (2007) *The Layers of National Innovation Systems: The Historical Evolution of a National Innovation System in Norway*. TIK working papers on Innovation Studies. University of Oslo: Oslo

List of acronyms, abbreviations and technical terms

Antibody: Protein used by the immune system to identify and neutralize foreign objects like bacteria and viruses

CGE&Y: Cap Gemini Ernst & Young

Dermatology: Diagnosis and treatment of diseases and tumors of the skin

CMBN: Centre for Molecular Biology and Neuroscience (2003-2012), Bioprospecting platform at SINTEF in collaboration with NTNU (2004-2007),

EBAN: European Business Angels Network

EMBL: European Molecular Biology Laboratory

FORNY: Sector unspecific pre-seed financing mainly given to TTOs (running)

FUGE: Functional genomics program (2002-2011)

GNBIO: Basic business oriented biotechnology program (2001-2008)

HIV: Human immunodeficiency virus (HIV) is a retrovirus that causes acquired immunodeficiency syndrome (AIDS), a condition in humans in which the immune system begins to fail

Lipids: Class of hydrocarbon-containing organic compounds (molecules which contain carbon)

MABIT: Research program related to commercial. exploitation of marine resources (1998-2008)

Marbank/Marbio: Marine biobank and bioprospecting platform at the University of Tromsø (2004-2007)

MEDKAP: Technology validation in biomedical research (terminated by 2007)

NFR: Research council of Norway

NHD: Ministry of trade and industry

Nutraceuticals: Combination of the words "nutrition" and "pharmaceutical" and refers to foods claimed to have a medicinal effect on human health

NYSE: New York Stock Exchange

Omega-3: Group of fatty acids

Oncology: The branch of medicine that studies tumors (cancer) and seeks to understand their development, diagnosis, treatment, and prevention.

OSE: Oslo Stock Exchange

PCT: Patent Co-operation Treaty

Peptides: family of short molecules which allow the creation of antibodies in animals without the need to purify the protein of interest

PRO: public research organization

PROSBIO: Industry initiated research related to biopharmaceuticals and processing industry (2002-2010),

BIOT2000: Applied research related to agricultural, aquaculture and environmental biotechnology (2000-2005)

Appendix: Notes on Methodology

This paper is trying to provide an initial and indicative overview of biotechnology business in Norway as of 2006-2007, but it should as mentioned in the introduction be noted that there are delimitations due to space and resource restrictions. Not included is otherwise important information such as financial status of firms, number and type of alliances, and detailed history of the firms in terms of origin. what has been done is to interpret and categorize the population of firms which have modern biotechnology as their primary or secondary activity. Firms were identified through industry sources (NorBioBase – a national database for the biotech industry), previously published reports (CGE&Y 2000; van Beuzekom 2001; Mabit 2002; Hernes et al. 2004; Marvik 2005; Normann 2007) and industry press (*EuroBiotech News*, *Nordic Life Science*). After assessing whether the firms seemed to meet the criterion of being relevant to modern biotechnology (i.e. traditional biotechnology firms such as breweries and bakeries etc. were excluded), the firms were confirmed as indeed existing in the sense of having submitted publicly available records regarding address, employee numbers and accounts as registered in the database Purehelp.no or via alternative confirmation in the case of two firms which were not registered there (Kilda Biolink and Balter Medical/Photosense). As for employee numbers information, except for the two exception firms mentioned above for the sake of consistency being refereed according to the database entries although the total numbers used in this paper are fairly sure to be lower than actual numbers. This is because many start-up firms are registered with only few or no employees, and have temporary project staff instead of regular employees. There is a certain risk that the actual total number of firms is underestimating the actual situation: 10 firms have not been included due to lack of necessary confirmation regarding the continued existence and activities (Alnæs Marine Oils, Ampligéne, Chameleon Pharma, Cryotech Seafood, Normedica, Velomar, Procaryo, ProVisage, Silfas, and TransHerba).

Neither have 11 firms referred to in relevant literature been included within the bio-chemical segment due to difficulties in determining whether they indeed conduct modern biotechnology (Biova, Drytech, Hordafôr, Kavli, Marin Lipids, Miljøprosess, Mills, Nutreco, Peter Møller, Skretting and Toro). One originally Norwegian firm is now Icelandic and seems to have only very limited activity in Norway has not been included (Primex Biochemicals). Neither have firms owned by Norwegian capital, but located entirely abroad, been included (e.g. Mentis Cura in Iceland and MediCult in Denmark).

Table 1: Biotechnology-related firms in Norway (June, 2007)

Characteristics / Product Area	Number of employees			Number of firms		Total firms	Location of firm headquarters in Norway			
	"Blue"	Others	Total	"Blue"	Others		East	West	Central	North
Pharmaceuticals	0	848	848	0	3	3	3	0	0	0
Therapeutics	224	73	297	9	16	25	18	3	2	2
Therapeutics/ Diagnostics	0	1417	1417	0	4	4	4	0	0	0
Diagnostics, analysis and drug delivery	0	305	305	0	38	38	25	8	2	3
Bio-informatics	0	25	25	0	7	7	4	1	2	0
Breeding / biobanks	317	69	386	5	5	10	6	0	1	3
Bio-chemical production etc.	783	153	936	35	12	47	14	17	3	13
Total	1324	2890	4214	49	85	134	74	29	10	21

Notes: For selection criteria, see appendix 1. Firm headquarters refer to office in Norway for the firms with foreign ownership. "Bio-chemical production etc." includes broad applications. Employee numbers not available for one firm each within Bio-informatics, Diagnostics and Therapeutics, and for one firm each within Breeding/biobanks and Bio-chemical production etc. the employee numbers are from other sources than Purehelp.no.
Sources: Compiled based on information from Purehelp.no (employee numbers); author's assessment when it comes to categorization.

Table 2: Year of establishment of biotechnology firms in Norway divided into segments

	1996>	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006-2007
Therapeutic	5	3	1	1	1	3	3	3	2	1	2
Therapeutic/ Diagnostic	4	0	0	0	0	0	0	0	0	0	0
Diagnostic	11	0	9	4	4	4	3	0	1	2	0
Bio-informatics	0	0	0	0	1	4	1	0	1	0	0
Breeding/biobanks	7	1	0	0	0	0	2	0	0	0	0
Bio-production and broad applications	20	2	2	1	4	5	5	1	2	4	1
Pharmaceutical	3	0	0	0	0	0	0	0	0	0	0

Sources: Compiled based on information from Purehelp.no (except for in the case for two firms); author's assessment when it comes to categorization.

Table 3: Venture capital characteristics ca. 2003

	Norway	Sweden	Denmark	Finland	Spain	UK	Canada	USA
Total venture capital investments in biotechnology, 2001 to 2003 combined (1)	74	323	159	29	14	502	721	9526
Percent of 2003 total venture capital in 23 countries combined	0.6	2.5	1.2	4.2	0.1	3.9	5.6	74.4
Biotechnology venture capital investments as a percentage of GDP, 2003	0.022	0.015	0.024	0.008	0.001	0.016	0.026	0.031
Number of investments	327	669	240	454	NA	NA	NA	NA
Total amount invested 2003 (2)	239	1056	232	386	NA	NA	NA	NA

Notes. 1. Millions USD. 2. Millions euro. Source: van Beuzekom and Arundel (2006) based on data from EVCA NVCA and CVCA for first three rows; Sørheim et al. (2006) for last two rows.

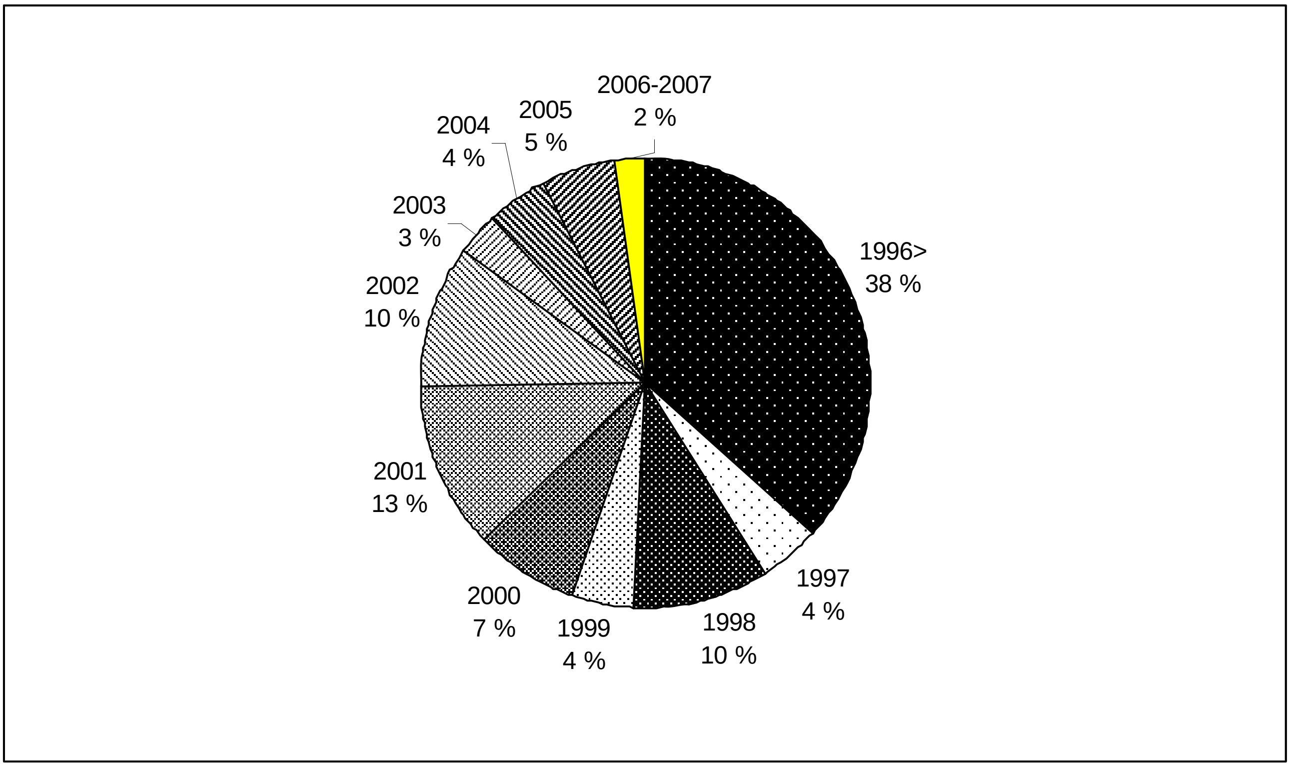


Fig. 1: Year of establishment of biotechnology firms in Norway (percent per year)

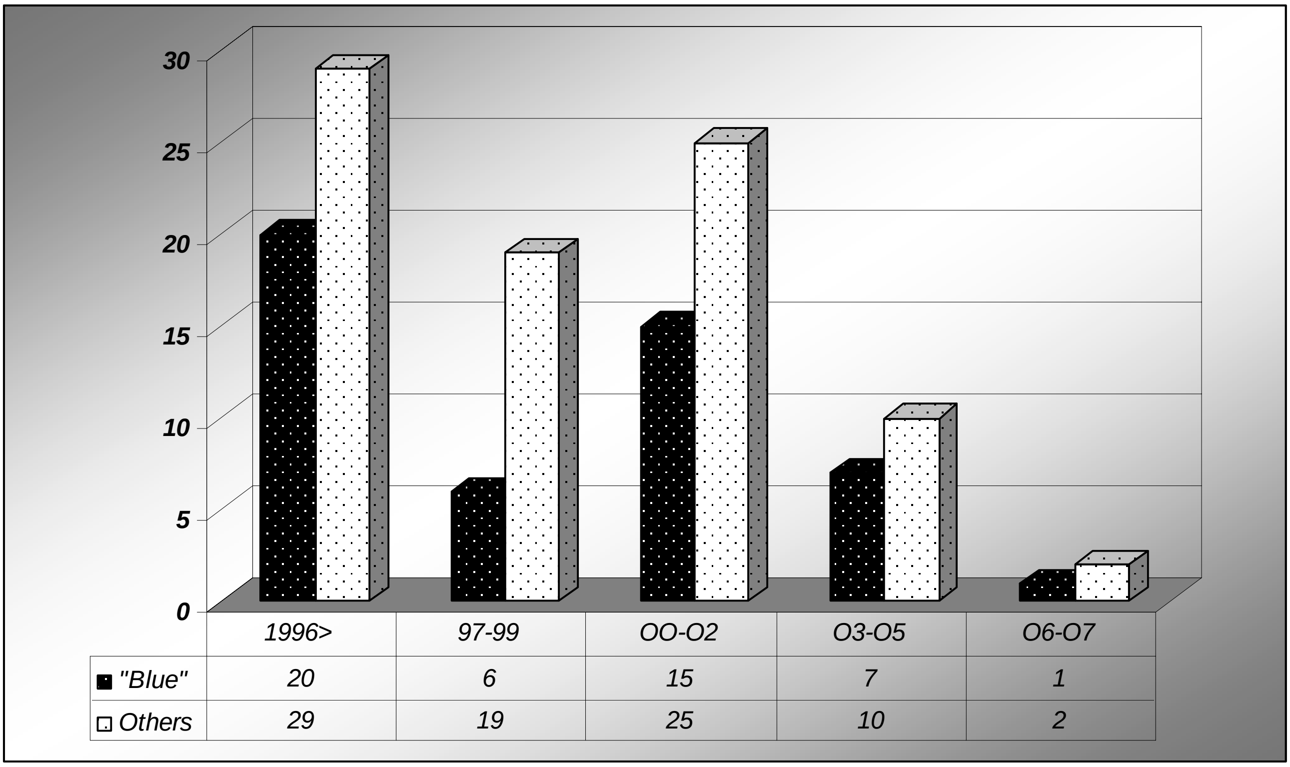


Fig. 2: Year of establishment of biotechnology firms in Norway, “Blue” firms vs. others

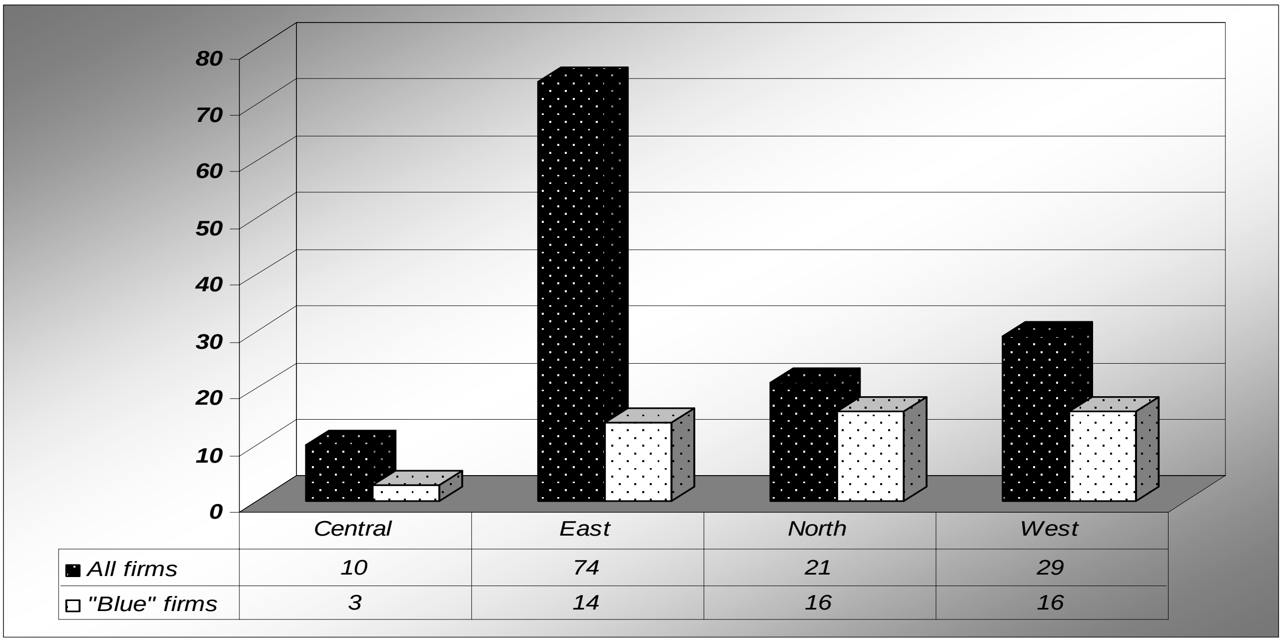
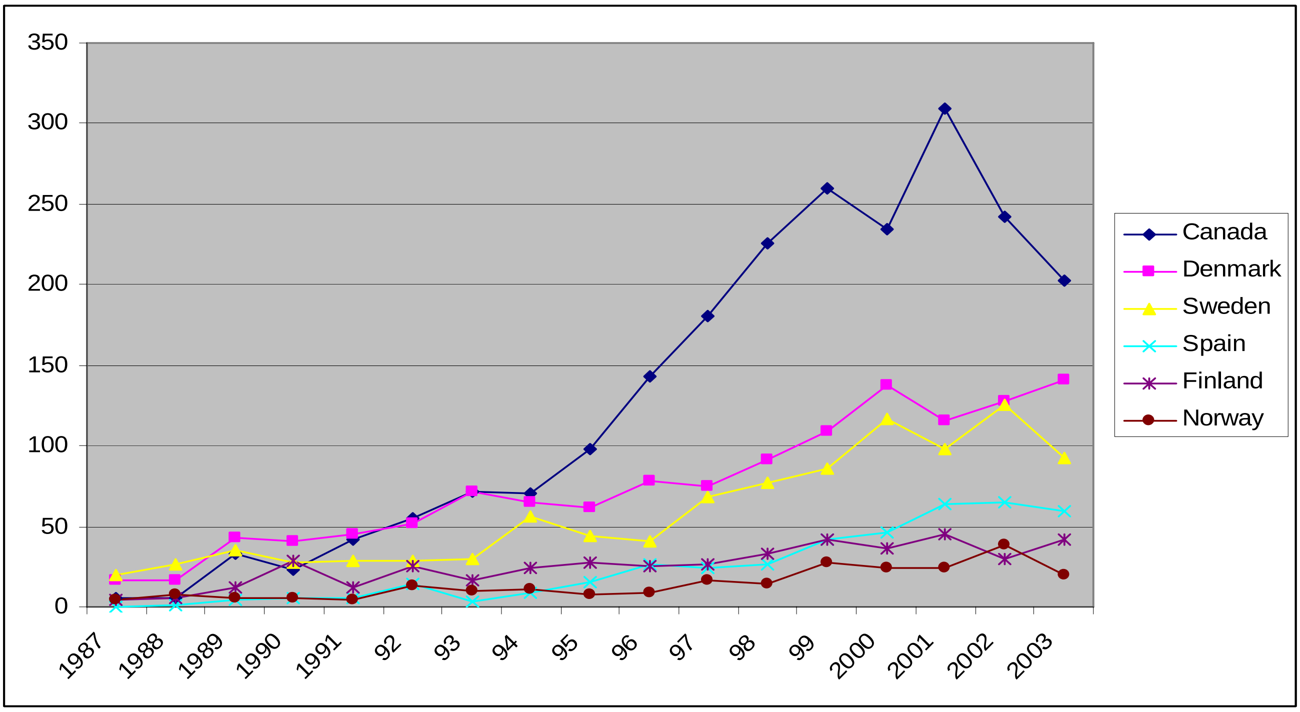


Fig. 3: Geographical distribution of firm



Notes: 1.The provisional definition of biotechnology patents is [A01H1/00,A01H4/00,A61K38/00,A61K39/00,A61K48/00,C02F3/34,C07G(11/00,13/00,15/00), C07K(4/00,14/00,16/00,17/00,19/00),C12M,C12N,C12P,C12Q,C12S,G01N27/327, G01N33/(53*,54*,55*,57*,68,74,76,78,88,92)]. Patent counts are based on the priority date, the inventor's country of residence and fractional counts.
Source: Compiled based on dataset attached to OECD (2006: 20).

Fig. 4: Number of biotechnology patents[1] filed under PCT

Box 1: Diagenic: "Today we are somewhere in between being small and not being small"

Chronology

1997 - Concept discovered
1998 - DiaGenic founded
2000 - Full time research
2002 - Proof of concept
2004 - First patent granted (US/EU) and listed on Oslo Stock Exchange
2005 - Scientific recognition
2006 - Prototypes developed
2007 - Frost & Sullivan Entrepreneurial Company of the Year Award in the European molecular diagnostics market . Announced capital expansion through issue of shares valued 28 million NOK

DiaGenic focuses on early disease detection of diseases. It has got 15 employees, two post- docs and one PhD-student, leading the self-assesment that "Today we are somewhere in between being small and not being small". As of 2007 the two targeted diseases are Alzheimer's and breast cancer. Although totally different, a common trait shared by the diseases is the lack of a "gold standard" for their detection them. The firm has concentrated on getting access to blood samples with good clinical data and developing competence on the diseases as a basis for technical solutions. In 2007 the firm announced the first validated prototypes for gene expression signature tests for the early diagnosis of the two diseases.

The innovativeness of the prototype lies in its non-invasive aspect, enabling detection of a disease through features examined elsewhere, in this case blood. The process for arriving at these solutions seems to be quite innovative as well, since the firm compensates for its lack of in-depth and continuously updated knowledge about the specific diseases in question by building collaboration with the University of Oslo.

Source: Compiled based on Diagenic (2007); GEN (2007), Lönneborg (2007)

Box 2: Mergers, de-mergers and acquisitions (highlights)

1984 Alpharma listed NYSE.

1995 Norsk Hydro sold out of Swedish BioInvent (acquired in 1990)

1997 Merger between Amersham and Nycoomed Imaging (later to be acquired by GE Healthcare)

1998 The firm Natural listed OSE. Pronova Biocare acquired all the shares in Lipro (est. 1877) based on cod liver oil production.

1999 Axis-Shield listed on London/ OSE.

2002 FMC BioPolymer acquired Pronova Biomedical, a supplier of alginates and chitosans.

2004 Sarsia acquires majority of shares in Danish Medi-Mush.

2005 NorDiag, Biotec Pharmacon and DiaGenic listed Oslo Stock Exchange. Dynal Biotech sold to Invitrogen. EPAX Sales and Production de-merged from Pronova Biocare, where Pronova focuses solely on the production of API/Omacor and EPAX producing Omega-3 oils for the dietary supplements industry.

2007 Algeta listed OSE. Nordiag acquires Genpoint. Aker BioMarine and Pronova Biocare signed a letter of intent to establish develop pharmaceutical products from krill. Natural merges with Aker Biomarine.

Sources: Compiled by author based on company home pages and industry press.

Box 3: The special case of public investment funds

State ownership in industry is relatively high in Norway, but as for investment in new start-ups, there is no political consensus on the appropriate approach. Part of this discussion concerns whether and to what degree the state should act as a direct owner in nominally private firms. The Government privatized the major state-owned player in the VC market (SND Invest) in 2003/2004, consistent with the recommendations made in a 2002 White Paper on state ownership. SND Invest was acquired by what is now known as Verdane Capital funds, formerly Four Seasons funds. Another initiative was the Start fund established in 1998 with 50-50 private and public participation. It was discontinued in this form in 2004 when a private fund management firm was asked to realize the value of the portfolio.

The remaining dominant state involvement in ownership as of 2007 is Argentum funds established in 2001, which invests only in other funds and not directly in firms. Argentums is one of the largest investors in Verdane Capital funds as well as in Teknoinvest III which has placements in firms like Photocure, the AKVA group supplying technology to the fish farming industry and a medical device company named BioForm Medical in addition to ICT related investments such as Trolltech, Opera Software, Funcom, and Tandberg.

Another public-private model is exemplified by Sarsia Innovation, which focuses on high-technology investments predominantly on a regional basis. 75% of Sarsia is owned by state investors and 25 percent by private investors. Portfolio companies include Medi-Mush, NorDiag, Novel Diagnostics, TIPOgen, PlasmAcute, and UniTargetingResearch in addition to non-biotech firms such as Environmental Solutions AS focusing on ship ballast water management technology and Epsis AS delivering services to the oil and gas industry

Sources: Argentum (2005), Louët (2004), Sarsia Innovation (2007), Teknoinvest II (2007), NHD (2006).

Box 4: Chronology of events, policies and institutional changes

1970-77 Scientists at the Oslo and Bergen universities initiate research involving recombinant DNA-technology

1977 New method for sequencing DNA published

1977-78 SINTEF establishes Norway's first biotechnology group with support from research council

1980 The corporation Amgen Inc. founded in the US

1980-84 Series of committees on biotechnology led by Laland (1980), Kleppe (1982) and Prydz (1984)

1985 Biotechnology became became one of five "main target areas" in the 1985 White Paper on research. Public scepticism towards biotechnology surfaced when a break-through in a research project on salmon

1985-86 New national action plan / biotech became one of five 'main target areas' in the 1985 White Paper on research policy with little or no attention paid to any other aspect than the immense economic and

research potential of the new technology. Increasing grants to biotechnology and research council action plan on biotechnology; Norway becomes member of EMBL

1987 Norway participates in Nordic cooperation program on biotechnology

1991 The Norwegian Biotechnology Advisory Board established.

1993 Gene technology Act passed. White Paper on humans and biotechnology.

1994 Biotechnology Act passed. European Laboratory for Marine Biotechnology established in Berge

1996 Perspective analysis and action plan for biotechnology for 1995-2005 presented

1997 Research Council presents Strategy for biotechnology

1998 National strategy for business oriented biotechnology

1998-2011 Series of biotechnology research programs, including large FUGE **-** Functional genomics program (2002-2011) (see complete list appended at end of paper)

2002 SkatteFUNN tax scheme for deduction on R&D investements for SMEs instituted

2002 University Act amendment regarding rights to inventions

2003 Act on biobanks

2006 Eurobarometer study shows increased optimism towards biotechnology amongst Norwegians

2007 Amendments to Biotechnology Law scheduled to be proposed to parliament

2008 Norway scheduled to become member of EPT

Sources: Compiled based on Kallerud (2004), Marvik (2005) and government and research council information material and news releases.